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Power Systems

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CLASS TEST 2019-2020

ELECTRICAL ENGINEERING

Date of Test : 09/09/2019

ANSWER KEY ➤ Power Systems

1.	(b)	7.	(d)	13.	(c)	19.	(d)	25.	(b)
2.	(a)	8.	(c)	14.	(b)	20.	(b)	26.	(d)
3.	(b)	9.	(c)	15.	(a)	21.	(a)	27.	(b)
4.	(b)	10.	(a)	16.	(d)	22.	(a)	28.	(d)
5.	(d)	11.	(c)	17.	(b)	23.	(d)	29.	(b)
6.	(b)	12.	(b)	18.	(c)	24.	(d)	30.	(b)

DETAILED EXPLANATIONS

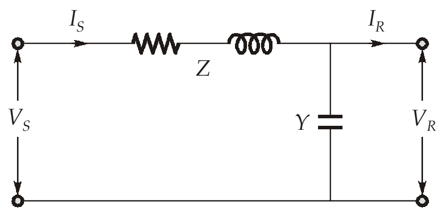
1. (b)

If x is the number of layers, then the total number of strands is obtained by,

$$N = (3x^2 - 3x + 1)$$
$$= 3(3^2) - (3 \times 3) + 1$$
$$= 27 - 9 + 1$$
$$N = 19$$

2. (a)

End condenser network:



$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$= \begin{bmatrix} 1+YZ & Z \\ Y & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Here $A \neq D$ therefore it is not symmetrical

$$AD - BC = 1 + YZ - YZ = 1$$

Therefore it is reciprocal.

3. (b)

$$\text{Reactive power, } Q = \frac{V}{X} \cdot \Delta V$$

$$Q = \frac{1}{0.4} \times \frac{7\,\text{kV}}{400\,\text{kV}}$$

$$Q = 0.04375 \text{ p.u.} = 0.04375 \times 1000 \text{ MVA}$$
$$= 43.75 \text{ MVAR}$$

4. (b)

$$\text{Phase constant, } \beta = 0.00314 \text{ radian/km}$$
$$\beta = 0.00314 \times 200 = 0.628 \text{ radians}$$
$$\beta = \frac{2\pi l}{\lambda}$$
$$\frac{l}{\lambda} = \frac{\beta}{2\pi} = \frac{0.628}{2\pi} = 0.10$$

$$\therefore \quad \text{Percentage ratio of } \frac{l}{\lambda} = 10\%$$

5. (d)

$$\text{Loss tangent of the cable} = \tan\delta = \frac{\frac{V}{R_i}}{V\omega C_i} = \frac{I_i}{I_c}$$

$$\tan\delta = \frac{1}{\omega C_i R_i} = \frac{1}{2\pi f C_i R_i} = \frac{1}{2\pi\times 50\times 1\times 10^{-6}\times 1\times 10^{6}}$$

$$= \frac{1}{100\pi}$$

6. (b)

For a T-model,

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1 & \frac{Z_L}{2} \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ Y_L & 1 \end{bmatrix}\begin{bmatrix} 1 & \frac{Z_L}{2} \\ 0 & 1 \end{bmatrix}\begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$= \begin{bmatrix} 1+\frac{Z_L Y_L}{2} & Z_L\left(1+\frac{Z_L Y_L}{4}\right) \\ Y_L & 1+\frac{Z_L Y_L}{2} \end{bmatrix}\begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\frac{A-1}{C} = \frac{1+\frac{Z_L Y_L}{2}-1}{Y_L} = \frac{Z_L}{2}$$

$$\therefore \quad \frac{Z_L}{2} = \frac{A-1}{C}$$

7. (d)

$$P_{\text{transmitted}} = VI \qquad \text{for 2-wire DC system}$$

$$= \text{constant}$$

$$\Rightarrow \quad V_1 I_1 = V_2 I_2$$

$$\text{or} \quad \frac{I_1}{I_2} = \frac{V_2}{V_1} = 2$$

$$P_{\text{loss}} = I^2 R_{\text{line}} = \text{Constant}$$

$$\Rightarrow \quad I_1^2 R_1 = I_2^2 R_2$$

$$\text{or} \quad \frac{R_2}{R_1} = \left(\frac{I_1}{I_2}\right)^2 = 4$$

$$\therefore \quad R_2 = 4R_1$$

Since conduction length is same (given),

$$\therefore \quad R \ \alpha \ \frac{1}{A}$$

$$\text{or,} \quad R \ \alpha \ \frac{1}{\text{Conductor material}}$$

Thus, $\quad (\text{Conductor material})_2 = \frac{1}{4}(\text{Conductor material})_1$

So, $\quad \text{Material saving} = \frac{3}{4}\ (\text{Conductor material})_1$

$\therefore \quad \text{Percentage material saving} = \frac{3}{4} \times 100 = 75\%$

8. (c)

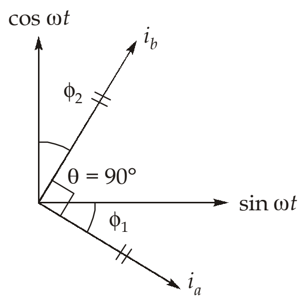
$$K = \frac{C_m}{C_s} = 0.20$$

$$V_3 = V_1(K^2 + 3K + 1) = 11\ (0.2^2 + (3 \times 0.2) + 1)$$

$$V_3 = 18.04 \text{ kV}$$

9. (c)

According to phasor diagram of a two phase system,



For balanced two phase system,

$$\theta = 90°$$

$$\therefore \quad \phi_1 = \phi_2$$

10. (a)

$$P_1 + P_2 + P_3 = 0$$

$$P_1 + 0.1 - 0.2 = 0$$

$$P_1 = 0.1 \text{ p.u.}$$

Power flow from bus 1 to 2 is zero

$$P_{12} = \frac{EV}{X}\sin(\delta_1 - \delta_2) = 0$$

$$\therefore \quad \delta_1 = \delta_2$$

As bus 1 is slack bus $\delta_1 = \delta_2 = 0$

$$P_{23} = \frac{V_2V_3}{X}\sin(\delta_2 - \delta_3)$$

$$0.1 = \frac{1 \times 1}{1}\sin(\delta_2 - \delta_3)$$

$$\delta_2 - \delta_3 = \sin^{-1}(0.1) = 0.1 \text{ rad}$$

$$\delta_3 = -0.1 \text{ rad}$$

11. (c)

$$(RRRV)_{\max} = \frac{V_m}{\sqrt{LC}} \qquad (X_L = 2\pi fL)$$

$$L = \frac{10}{2 \times \pi \times 50} = 0.0318$$

$$(RRRV)_{max} = \left(\frac{400}{\sqrt{3}} \times \sqrt{2}\right) \times \frac{1}{\sqrt{0.0318 \times 0.040 \times 10^{-6}}}$$

$$(RRRV)_{max} = 9.16 \text{ kV/}\mu\text{s}$$

12. (b)

We know that, $$X_L = \frac{B}{1-A} = \frac{36.54}{1-0.99} = 3654\ \Omega$$

$$L = \frac{X_L}{2\pi f} = \frac{3654}{2 \times \pi \times 50}$$

$\Rightarrow$ $$L = 11.63 \text{ H}$$

13. (c)

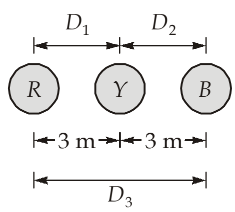
At SIL, the VARs consumed by series inductance of line are equal to the VARs generated by shunt capacitance of line so no VARs is required by transmission line. Hence at all the points on the line there is in phase voltage and current, i.e. upf, i.e. flat voltage.

14. (b)

$$(\text{SIL})_N = (\text{SIL})_{old} \times \sqrt{1+K_1} = (\text{SIL})_{old} \times \sqrt{1+0.3}$$

$$\% \text{ change} = \frac{\sqrt{1.3}-1}{1} \times 100 = 14.02\%$$

15. (a)



$$\text{Inductance, } L = \frac{\mu_0}{2\pi}\ln\left(\frac{d}{r'}\right) = \frac{\mu_0}{2\pi}\ln\left(\frac{(D_1D_2D_3)^{1/3}}{r'}\right) = 2 \times 10^{-7}\ln\left(\frac{(3\times3\times6)^{\frac{1}{3}}}{0.7788 \times \frac{10^{-2}}{2}}\right)$$

$$L = 1.375 \text{ mH/km/phase}$$

16. (d)

For cable, insulation resistance and length relationship is:

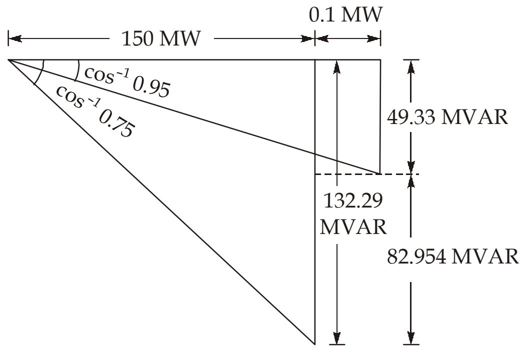
$$R \propto \frac{1}{l}$$

$\therefore$ $$\frac{R_1}{R_2} = \frac{l_2}{l_1}$$

$\Rightarrow$ $$R_2 = \frac{25 \times 100}{180}$$

$$R_2 = 13.89\ \text{M}\Omega$$

17. (b)



Without Synchronous motor:

$$Q_1 = S_1 \sin\phi_1 = \frac{150}{0.75}\sin(\cos^{-1}0.75)$$

$$Q_1 = 132.29 \text{ MVAR}$$

With Synchronous motor:

$$Q_2 = S_2 \sin\phi_2 = \frac{150+0.1}{0.95}\sin(\cos^{-1}0.95)$$

$$Q_2 = 49.33 \text{ MVAR}$$

$$\text{VAR supplied by motor} = 82.954 \text{ MVAR}$$

18. (c)

Self GMD for 4 bundled conductors

$$D_S = \left(r' \times s \times s \times \sqrt{2}s\right)^{1/4}$$

$$= \left(0.7788 \times 0.5 \times 10^{-2} \times 1 \times 1 \times \sqrt{2}\right)^{1/4} = 0.272 \text{ m}$$

19. (d)

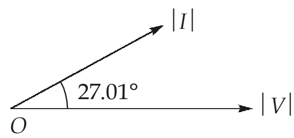
$$Y_{eq} = \frac{1}{50} + \frac{1}{j(2\pi \times 50 \times 0.15)} + j(2\pi \times 50 \times 100 \times 10^{-6})$$

$$Y_{eq} = 0.0224\angle 27.01° \ ℧$$

$$Z_{eq} = 44.64\angle{-27.01°} \ \Omega$$

$$I = \frac{100\angle 0°}{44.64\angle -27.01°}$$

$$= 2.24\angle 27.01° \text{ A}$$



$$\text{The input power factor} = \cos(27.01°) = 0.89 \text{ leading}$$

20. (b)

$$\text{Let base impedance} = Z_B$$

$$X_{(\Omega)} = 0.025\, Z_B$$

$$Y_{(℧)} = \frac{1.4}{Z_B}$$

Assuming inductance of line, L H/km and capacitance as C F/km.

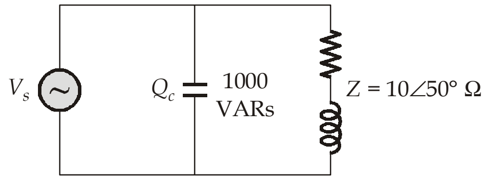
$$X = \omega l L$$
$$Y = \omega l C$$
$$L = \frac{X}{\omega l} = \frac{0.025 Z_B}{\omega l}; \qquad C = \frac{Y}{\omega l} = \frac{1.4}{\omega l Z_B}$$

Velocity of propagation is,

$$v = \frac{1}{\sqrt{LC}}$$
$$3 \times 10^5 = \frac{1}{\sqrt{\frac{0.025 Z_B}{\omega l} \times \frac{1.4}{\omega l Z_B}}}$$
$$\text{Length of the line, } l = \frac{\sqrt{0.025 \times 1.4} \times 3 \times 10^5}{2\pi \times 50} = 178.65 \text{ km}$$

21. (a)

$$\text{Load current, } I = \frac{V_s}{Z} = \frac{220\angle 0°}{10\angle 50°}$$
$$I = 22\angle -50° \text{ A}$$



Real power supplied by source is,

$$P_s = |V||I|\cos\phi$$
$$= 220 \times 22 \times \cos(50°) = 3111 \text{ W}$$

22. (a)

At no load, $V_S = A\, V_R$

$$V_{R\,(NL)} = \frac{V_S}{A} = \frac{240}{0.91} = 263.73 \text{ kV}$$

The percentage voltage regulation is,

$$\% VR = \frac{V_{R(NL)} - V_{R(FL)}}{V_{R(FL)}} \times 100$$
$$= \frac{263.73 - 220}{220} \times 100 = 19.87\%$$

23. (d)

From the given voltages,

$$I_a = \frac{V_{an}}{R} = \frac{10\angle 0°}{R}$$
$$I_b = \frac{V_{bn}}{jX_L} = \frac{10\angle -120°}{j1} = 10\angle 150° \text{ A}$$

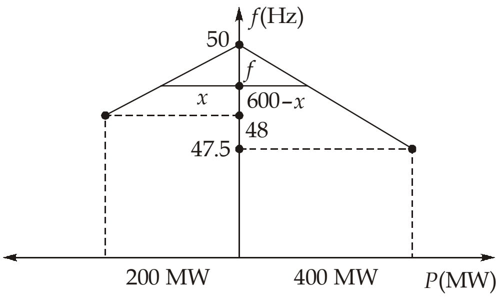
$$I_c = \frac{V_{cn}}{-jX_C} = \frac{10\angle 120^\circ}{-j1} = 10\angle -150^\circ \text{A}$$

Given,

$$I_n = 0 = I_a + I_b + I_c = \frac{10\angle 0^\circ}{R} + 10\angle 150^\circ + 10\angle -150^\circ = 0$$

$$R = 0.577\ \Omega$$

24. (d)



$$\frac{50-f}{x} = \frac{50-48}{200}$$

$$0.01\,x + f = 50 \qquad \text{...(i)}$$

and

$$\frac{50-f}{600-x} = \frac{50-47.5}{400}$$

$$50 - f = 3.75 - 6.25 \times 10^{-3}\,x$$

$$6.25 \times 10^{-3}\,x - f = -46.25 \qquad \text{...(ii)}$$

$$x = 230.77 \text{ MW}$$

From equation (i),

$$(0.01 \times 230.77) + f = 50$$

$$f = 47.69 \text{ Hz}$$

25. (b)

3-ϕ fault current:

Let system is under no load condition before fault,

$\therefore$ $$E = 1\angle 0^\circ \text{ p.u.}$$

$$\text{3-}\phi \text{ fault current, } I_f = \frac{E}{X_1}$$

$\Rightarrow$ $$X_1 = \frac{1}{-j5} = j0.2 \text{ p.u.}$$

Line-line fault current:

$$I_f = \frac{\sqrt{3}E}{X_1 + X_2}$$

$\Rightarrow$ $$X_1 + X_2 = \frac{\sqrt{3}}{-j2.5}$$

$\Rightarrow$ $$j\,0.2 + X_2 = j\,0.69 \text{ p.u.}$$

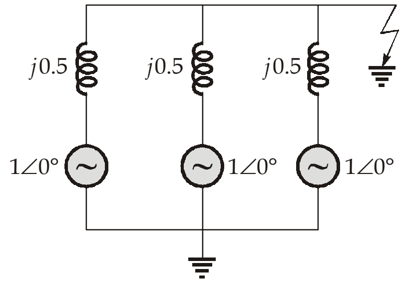
$\Rightarrow$ $$X_2 = j\,0.49 \text{ p.u.}$$

26. (d)

$$Z_{\text{Bus (new)}} = \begin{bmatrix} 0.3 & 0.3 \\ 0.3 & 0.3+0.5 \end{bmatrix} = \begin{bmatrix} 0.3 & 0.3 \\ 0.3 & 0.8 \end{bmatrix}$$

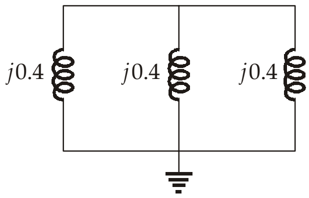
27. **(b)**

Positive sequence reactance diagram:



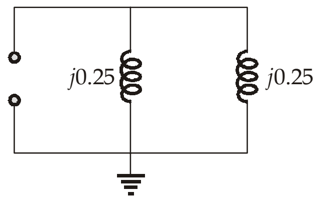
$$\Rightarrow \qquad Z_{01} = j\frac{0.5}{3}$$

Negative sequence reactance diagram:



$$\Rightarrow \qquad Z_{02} = j\frac{0.4}{3}$$

Zero sequence reactance diagram:



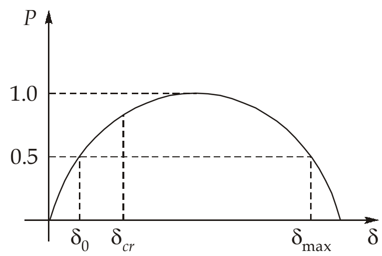
$$\Rightarrow \qquad Z_{00} = j\frac{0.25}{2}$$

$$I_f = 3\left(\frac{E}{Z_{01}+Z_{02}+Z_{00}}\right) = 3\left(\frac{1}{j0.425}\right)$$

$$I_f = -j7.058 \text{ p.u.}$$

$$\Rightarrow \qquad |I_f| = 7.058 \text{ p.u.}$$

28. **(d)**



$$P_m = P_{max} \sin \delta_0$$

$$\sin \delta_0 = 0.5$$

$$\delta_0 = 30° \text{ or } \frac{\pi}{6} \text{ rad}$$

and

$$\delta_{max} = \pi - \delta_0 = \pi - \frac{\pi}{6} = \frac{5\pi}{6} \text{ rad or } 150°$$

$$\cos \delta_{cr} = \frac{P_m}{P_{max}}(\delta_{max} - \delta_0) + \cos\delta_{max} = \frac{0.5}{1}\left(\frac{5\pi}{6} - \frac{\pi}{6}\right) + \cos(150°)$$

The critical clearing angle,

$$\delta_{cr} = \cos^{-1}(0.18117) = 79.562°$$

29. (b)

Sum of the line currents in a Δ is always zero

$$I_a + I_b + I_c = 0$$

$$I_b = -I_a$$

$$I_{a1} = \frac{1}{3}\left[I_a + \alpha I_b + \alpha^2 I_c\right] = \frac{1}{3}[I_a - \alpha I_a]$$

$$= \frac{I_a(1 - 1\angle 120°)}{3} = \frac{(10\angle 0°)(1 - 1\angle 120°)}{3}$$

$$I_{a1} = 5.77\angle -30° \text{ A}$$

30. (b)

$$S_{D2} = (0.8 + j0) \text{ p.u.}$$

This 0.8 p.u. active power is supplied by the generator G_1

$$\therefore \quad 0.8 = \frac{1 \times 1}{0.5}\sin\delta$$

$$\delta = \sin^{-1}\left(\frac{0.8}{2}\right) = 23.58°$$

$$Q_R = \frac{|V_1| \times |V_2|}{X}\cos\delta - \frac{|V_1|^2}{X}$$

$$= \frac{1}{0.5}\cos(23.58°) - \frac{1}{0.5}$$

$$Q_R = -0.167 \text{ p.u.}$$

The VAR rating of the capacitor = 0.167 p.u.

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